JOURNAL OF ANIMAL SCIENCE
The Premier Journal and Leading Source of New Knowledge and Perspective in Animal Science

Behavior of steers grazing monocultures and binary mixtures of alfalfa and tall fescue

D. H. Seman, J. A. Stuedemann and N. S. Hill

J Anim Sci 1999. 77:1402-1411.

Behavior of Steers Grazing Monocultures and Binary Mixtures of Alfalfa and Tall Fescue[1]

D. H. Seman*,[2], J. A. Stuedemann*, and N. S. Hill†

*USDA-ARS, J. Phil Campbell Sr. Natural Resource Conservation Center, Watkinsville, GA 30677 and †University of Georgia, Athens 30602

ABSTRACT: Spectral analysis was used to relate dietary quality and herbage species to the behavior of grazing steers. Four .3-ha paddocks were established with either 'AU-Triumph' tall fescue (F; *Festuca arundinacea* Schreb.), 'Apollo' alfalfa (A; *Medicago sativa* L.), 1/3 fescue and 2/3 alfalfa (2/3A), or 2/3 fescue and 1/3 alfalfa (1/3A). Each paddock was stocked with 10 to 16 steers and defoliated in 5 d. Three steers on each paddock carried vibracorders to monitor grazing time. Daily forage samples were taken in 10-cm layers and weighed. Esophageal extrusa were collected from fistulated steers to measure diet quality. Daily grazing time did not differ (P = .37) among treatments; however, steers grazing mixtures grazed numerically longer (1.4 h/d) than steers on monocultures. Spectral analysis revealed that steers grazing A and 2/3A had many daily meals of short duration, but steers grazing 1/3A and F consumed three meals daily at 8-h intervals. Throughout the 4.67-d grazing period, quality of the diet linearly declined in crude protein and herbage digestibility, linearly increased in neutral detergent fiber and cellulose, and exhibited quadratic changes in lignin and ash. For most quality values, the tall fescue monoculture differed from the others ($P < .05$). Steers selected diets with similar quality for the A, 2/3A, and 1/3A treatments. This study illustrates how differences in forage diets alter grazing behavior of steers.

Key Words: Bovidae, Grazing, Time Series, Alfalfa, *Festuca arundinacea*

 J. Anim. Sci. 1999. 77:1402–1411

Introduction

Grazing behavior of steers grazing tall fescue (*Festuca arundinacea* Schreb.) changes in the presence of the endophytic fungus (*Neotyphodium coenophialum* (Stuedemann et al., 1989; Seman et al., 1990, 1997; Coffey et al., 1992; Howard et al., 1992). Adams (1985) found that grazing patterns and time spent grazing by beef steers could be altered by changing the time of day at which supplement was fed. Penning et al. (1991) found that nonlactating ewes consumed more meals of shorter duration when grazing white clover than when grazing perennial ryegrass. Because bovine grazing behavior can be affected by dietary components in the feed and by sward characteristics (Penning et al., 1991), we sought to determine whether changes in dietary quality and species of plant could influence the behavior of steers grazing alfalfa (*Medicago sativa* L.) and tall fescue (Parsons et al., 1994). Sward structure, amount of available forage, and species of grazed forage influences bite size, grazing time, and total intake rate (Chacon and Stobbs, 1976; Forbes, 1988; Penning et al., 1991). Because bite size, bites per minute, and intake rate are difficult and laborious to measure, we sought an easier method to detect differences in grazing behavior. Because bovine grazing behavior follows circadian rhythms associated with intake and digestion (Beauchemin et al., 1990; Deswysen et al., 1993; Champion et al., 1994), we used spectral analysis to characterize these rhythms.

The objective of this experiment was to investigate how time spent grazing and forage intake changed as alfalfa and tall fescue monocultures or alfalfa/fescue mixtures were defoliated by steers. Changes in forage characteristics were also measured.

[1]Mention of a proprietary product does not constitute a guarantee or warranty of the product by USDA, University of Georgia, or the authors and does not imply its approval to the exclusion of other products that may also be suitable. The USDA-ARS, South Atlantic Area, is an equal opportunity/affirmative action employer and agency services are available without discrimination.

[2]To whom correspondence should be addressed: 1420 Experiment Station Road (phone: (706)769-5631, ext. 210; fax: (706)769-8962; E-mail: dseman@arches.uga.edu).

Received August 31, 1998.
Accepted January 21, 1999.

Experimental Procedure

Pastures

Four .3-ha paddocks were established in a completely randomized design. One paddock was seeded with 'AU-Triumph' tall fescue (**F**) at 23.52 kg/ha. Another paddock was seeded with 'Apollo' alfalfa (**A**) at 23.52 kg/ha. A third paddock was seeded with 7.84 kg/ha of 'AU-Triumph' tall fescue and 15.68 kg of 'Apollo' alfalfa/ha (**2/3A**). The fourth paddock was seeded with 15.68 kg/ha of 'AU-Triumph' tall fescue and 7.84 kg/ha of 'Apollo' alfalfa (**1/3A**).

The forage in these paddocks had accumulated since the paddocks had been mob-grazed to a relatively uniform height earlier in the year. At the beginning of the 4.7-d study (September 19, 1988), initial forage (kg/ha) was 2,201 for A, 2,191 for 2/3A, 2,313 for 1/3A, and 1,508 for F. Botanical composition was estimated on February 27, 1988, by a point-quadrat method with 100 points counted per pasture. Botanical composition indicated that A was 77% alfalfa, 2% fescue, and 21% weeds; 2/3A was 74% alfalfa, 14% fescue, and 12% weeds; 1/3A was 55% alfalfa, 31% fescue, and 14% weeds; and F was 0% alfalfa, 73% fescue, and 17% weeds.

Cattle and Grazing Time

Each paddock was stocked with 10 to 16 yearling Angus steers to defoliate them in approximately 5 d. Three "tester" steers (mean = 300 kg, SD = 16 kg) were randomly assigned to each paddock and were fitted with vibracorders (Stobbs, 1970) to measure when and for how long grazing took place. Prior to this study, these steers had been grazing Coastal bermudagrass (*Cynodon dactylon* [L.] Pers.). Therefore, the forage species to which they were assigned was new to them. During the 4.67-d study, grazing time measurements were started at 1700 on Monday, September 19, 1988, and ended at 1200 on Saturday, September 24, 1988. Maximum and minimum ambient temperatures during the study averaged 29.9 and 18.4°C, respectively, with no precipitation during the experiment.

Forage Quality Measurements

Six esophageally fistulated Angus steers were used to estimate the quality of the grazed forage. Each paddock was grazed by three of the six steers at 0900 each morning. Because only two paddocks could be sampled during any one period, steers were randomly assigned to two pastures for sampling, and the other pastures were randomly selected for order of grazing. Steers were without feed overnight prior to obtaining esophageal samples. Extrusa were freeze-dried and ground to pass a 1-mm screen in a Wiley mill. The ground sample was divided in half, and one of the halves was ground a second time through a 1-mm screen using a Cyclone mill.

Tissue from esophageal samples that were ground through the Cyclone mill were scanned with a near-infrared scanning spectrophotometer (Hill et al., 1989). Crude protein, IVDMD, NDF, ADF, lignin, and ash were predicted from previous calibration equations developed for pasture, esophageal, and fecal samples. Sample values were validated by selecting 20 esophageal samples at random and conducting laboratory analyses for CP, IVDMD, NDF, ADF, ash, and lignin using tissue ground through the Wiley mill. Standard errors of validation ranged from 4 mg/kg for lignin to 32 mg/kg for IVDMD.

Sward Characteristics

One-half-meter square quadrats were randomly placed at eight locations within each paddock each day, and forage was harvested in 10-cm layers using battery-powered clippers. Forage from each stratum was bagged and handled separately.

Spectral Analysis

Spectral analysis was used to investigate the cyclical nature of grazing behavior. Spectral analysis is most appropriate when observations are in sequential order, with equal time increments, the same duration, and with no missing values. When comparing different time series, the series must have the same number of observations. In this case, 10 tester steers completed the 112-h study, two steers had malfunctioning vibracorders, one from 1/3A and one from F, and their data were deleted from the analysis.

The total variance of the spectral data was partitioned into sums of squares for the different cyclical components. These cyclical components were identified by Fourier frequencies ($\omega = 2\pi/n$) with a total of n/2 frequencies, where n is the number of observations in the time series. For each Fourier frequency, an ordinate, or sum of squares, was calculated as follows:

$$I(\omega) = \left[\left\{\sum_{t=1}^{n} yt\cos(\omega t)\right\}^2 + \left\{\sum_{t=1}^{n} yt\text{sine}(\omega t)\right\}^2\right]/n$$

where $I(\omega)$ is the ordinate owing to each Fourier frequency (ω) and n is the number of observations in the time series.

Ordinates were plotted vs cycle length on a periodogram. Significant ordinates were identified using an F-test to determine whether the coefficients of the sine and cosine functions were equal to zero, and no significant cycle was detected (Fuller, 1976).

Spectra for two grazing treatments were compared by generating a composite ordinate, $\bar{I}(\omega)$, which was computed as the average of all the steer ordinates on a paddock at each Fourier frequency, or:

$$\bar{I}(\omega_j) = r^{-1} \sum_{k=1}^{r} Ik(\omega_j)$$

where r is the number of steers and $I_k(\omega)$ is the ordinate of the k^{th} series at frequency $\omega = 2\pi/n$ (Diggle, 1990).

To compare grazing spectra averages, $\bar{I}_1(\omega)$ and $\bar{I}_2(\omega)$ based on r_1 and r_2 steers in these averages, the following ratio is calculated:

$$R(\omega) = \frac{\bar{I}_1(\omega)}{\bar{I}_2(\omega)}$$

with an F distribution with $2r_1$, $2r_2$ degrees of freedom (Diggle, 1990). The ratio was graphed with the critical upper and lower F-values, indicating significant, pointwise differences when the ratios exceeded the F boundaries. Differences between two entire spectra were tested using the maximum and minimum $R(\omega)$ (Diggle, 1990), and the probabilities for the F distribution for this test were calculated with the FDIST function in Excel (Microsoft Corp., Redmond, WA).

The SPECTRA Procedure of SAS (Brocklebank and Dickey, 1986) was used to calculate time series ordinates for each of 10 steers in the analysis. The ordinates were imported into a spreadsheet computer program, and the ordinate average was calculated for both treatments. The Fisher-Kappa test was used to detect whether a dominant grazing cycle was present in each forage treatment (Fuller, 1976). The ratios of the ordinates were plotted with the 5 and 95% critical values vs cycle length. Means of time spent grazing and forage quality fractions were calculated with the MEANS Procedure of SAS (1985). Because the paddock was the experimental unit and paddocks were not replicated in this study, grazing time and intake/min were regressed on actual percentage of fescue with PROC GLM of SAS to determine whether there was a curvilinear relationship. The model used was grazing time or intake = $b_0 + b_1$(%fescue) + b_2(%fescue^2).

Results and Discussion

Total average time spent grazing and estimated forage intake are presented in Table 1. Steers grazed for 1,578, 1,970, 1,919, and 1,786 min/steer during the 6,720-min (4.67 d) grazing period for the A, 2/3A, 1/3A, and F treatments, respectively. Even though steers grazing the mixtures spent slightly more time grazing than steers grazing monocultures, these numerical differences were not significant. When grazing time was regressed on percentage of fescue (botanical composition), neither linear (P = .37) nor quadratic (P = .38) effects were significant. Had the quadratic effect of percentage of fescue been significant, one could argue that steers spent more time grazing forage mixtures than monocultures. Approximate forage intake was calculated from daily forage measurements by assuming that no forage growth occurred during the study and forage disappearance was due to consumption by steers only. Forage consumption estimates indicated that as the proportion of tall fescue increased in the forage, intake linearly decreased (P = .531, R^2 = .737, intake [g/min] = 15.64 − .034 × percentage of fescue) from 14.84 and 16.61 for A and 2/3A to 11.59 g forage dry matter/min for F. Initial and ending amounts of above-ground forage indicated that the steers removed from 45.9 to 63.7% of the forage during this study. Both the total forage removal and percentage of forage used declined as the proportion of alfalfa declined in the mixture.

Figure 1 shows how quality of forage selected by steers changed during defoliation as determined from esophageal samples. Steers seemed to have the ability to select diets similar in quality when alfalfa was present in the pasture. Steers grazing tall fescue had lower-quality diets than those on the other pasture treatments, but there was an interaction between treatment and day of observation (P < .05) for all measures of forage quality except IVDMD. The interaction occurred because quality of the fescue diet changed less during the study than did quality of alfalfa and mixture diets. As the study progressed, diet quality exhibited a linear decline in crude protein and digestibility, a linear increase in NDF and cellulose, and quadratic changes in lignin and ash.

Table 1. Summary of sward characteristics, grazing time, and intake estimates

Trt[a]	Animal days	Forage, kg DM/ha		Total forage removed kg/ha	Forage use, %	Avg forage removed, kg·steer^{-1}·ha^{-1}·d^{-1}	Avg grazing time min/steer	Total forage intake, g·min^{-1}·steer^{-1}
		Initial	Final					
A	90	2,252	1,059	1,193	52.9	4.9	1,578	14.84
2/3A	90	2,350	823	1,527	64.9	6.3	1,970	16.61
1/3A	84	2,366	1,171	1,196	49.4	5.3	1,919	13.41
F	60	1,515	832	683	45.1	4.1	1,786	11.59

[a]Treatment A was pure 'Apollo' alfalfa sowed at a rate of 23.5 kg/ha. Treatment 2/3A was 15.7 kg/ha of 'Apollo' alfalfa sowed with 7.8 kg/ha of 'AU-Triumph' tall fescue. Treatment 1/3A was 7.8 kg/ha of 'Apollo' alfalfa sowed with 15.7 kg/ha of 'AU-Triumph' tall fescue. Treatment F was 23.5 kg/ha of 'AU-Triumph' tall fescue.

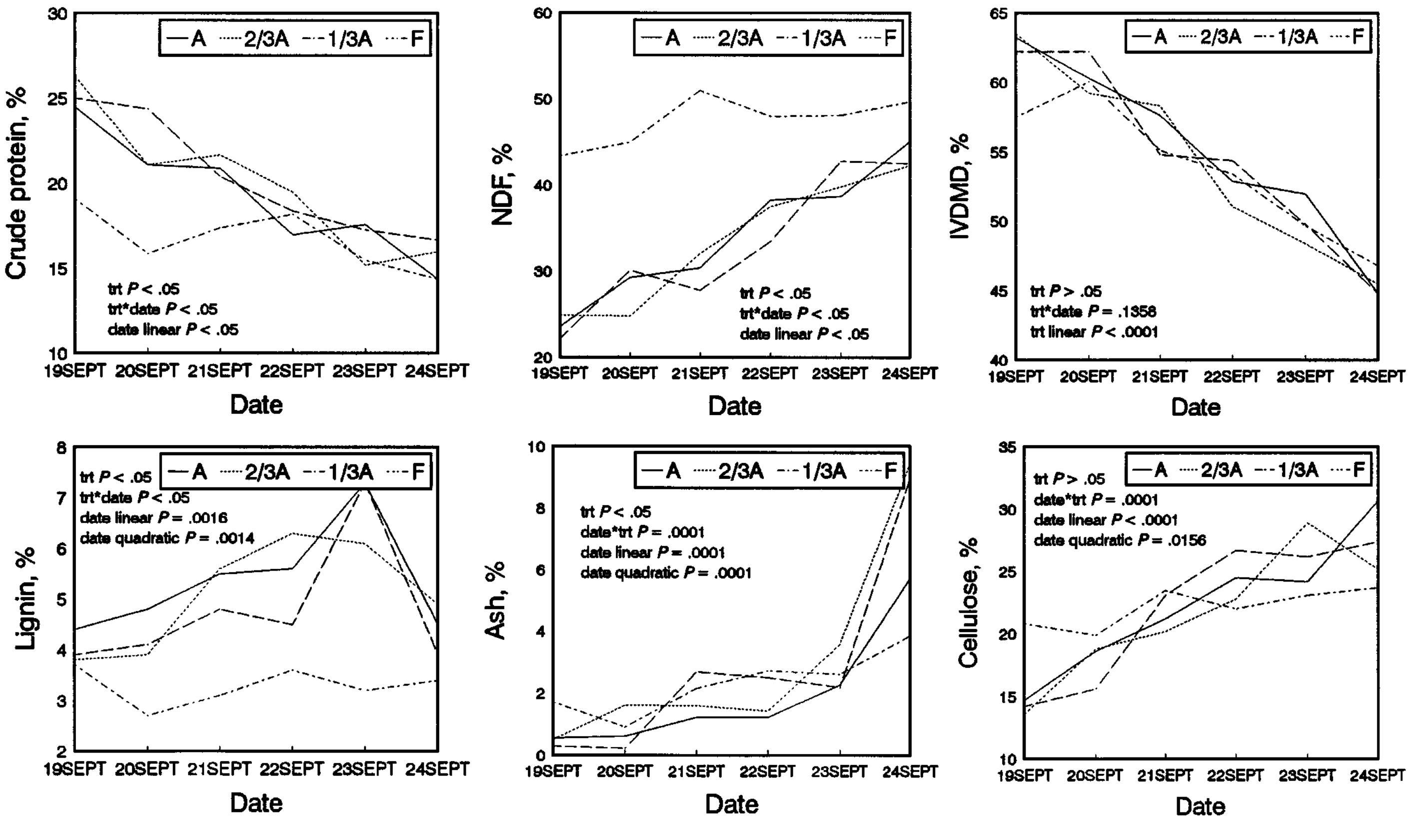

Figure 1. Quality measures of esophageal extrusa from steers consuming 'Apollo' alfalfa, 'AU-Triumph' tall fescue, and two alfalfa/fescue mixtures.

The decline in diet quality was probably due to a reduced proportion of leaves remaining in the forage (Chacon and Stobbs, 1976; Dougherty et al., 1990) as the forage was defoliated. Cattle have been shown to select and consume forage that is of greater quality than the average of the sward (Chacon and Stobbs, 1976). During heavy defoliation, Chacon and Stobbs (1976) showed that sward IVDMD was less (47.8%) than when the sward was grazed leniently (51.2%). Personal observations revealed that grazing steers removed alfalfa leaves, leaving standing stems remaining on d 6.

Even though averages of time spent grazing were not different among the four treatments, differences existed in how the steers behaved as they grazed. Periodograms describing differences in behavior of steers on the four forage treatments are presented in Figure 2. For A and 2/3A, no dominant cycles were evident, because the ordinates never exceeded the critical F-value at any cycle length. Because the Fisher-Kappa test, which tests for sinusoid buried noise, was not significant ($P > .05$), there was no dominant grazing cycle. The figure reveals that numerous cycles of 2 to 8 h occurred, indicating that steers consumed numerous, but short, meals.

Figure 2 shows that steers grazing 1/3A followed a pattern of grazing different from that followed by steers grazing A or 2/3A. In this periodogram, cycles of short duration have become nonsignificant, and cycles 8 or 24 h in length dominate. The Fisher-Kappa test indicated a significant, dominant cycle with an 8-h length. The F periodogram continues this trend: the short cycles have vanished, leaving only a cycle with a significant 8-h length. These periodograms suggest that F steers consumed three main meals daily, spaced approximately 8 h apart. As the proportion of fescue increased in the paddocks, grazing behavior of the steers became more similar to that of steers grazing tall fescue.

The ratio of ordinates was calculated to determine whether grazing cycling was different between treatments. Figure 3 shows the ratio of A/F. Cycle lengths for which the ratio exceeds the critical F-values indicate pointwise treatment differences. This figure shows that the major differences between the A and F grazing behavior occurred because A steers followed numerous grazing cycles of less than 4 h.

The major differences between 2/3A and F (Figure 3) occurred at the 2-, 8-, and 12-h cycle lengths. The two spectra were different ($P < .05$) according to the probability calculated from the maximum and minimum ratios. Steers grazing pure F and 1/3A were not different because the ratio of ordinates did not exceed the F critical values at any frequency. The probability associated with the maximum and minimum ratios also indicated no difference ($P > .05$) between spectra.

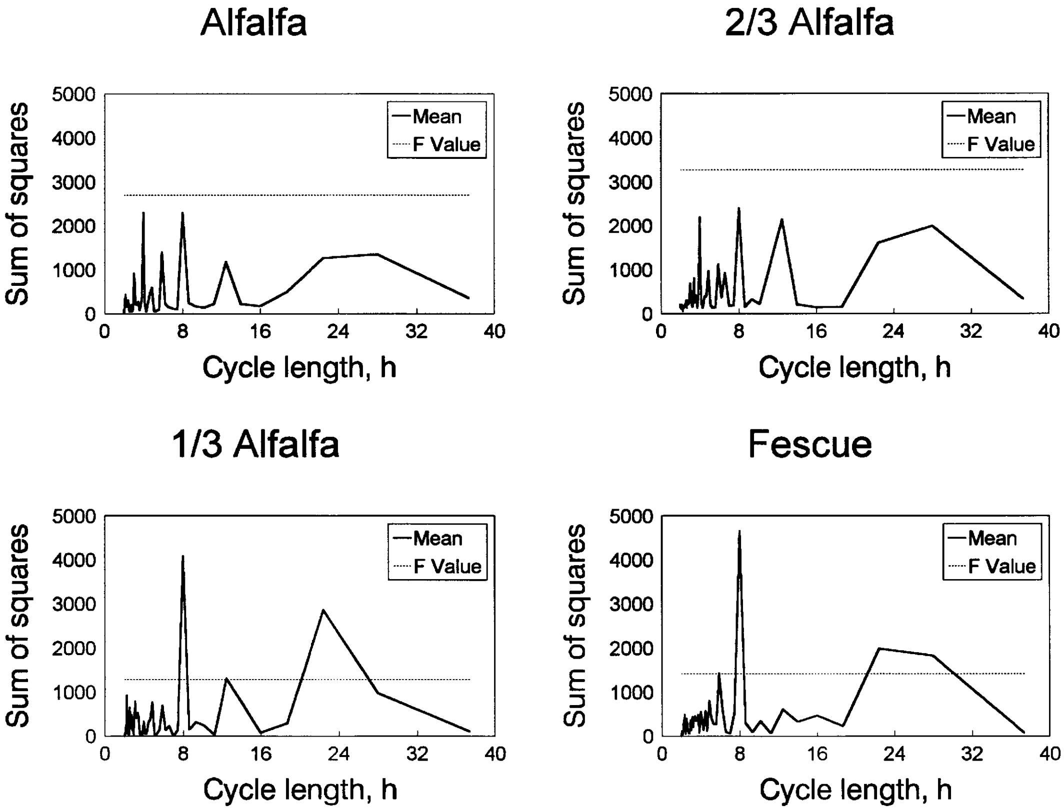

Figure 2. Periodograms of grazing time from steers grazing 'Apollo' alfalfa and 'AU-Triumph' tall fescue monocultures, or 2/3 'Apollo' alfalfa and 1/3 'AU-Triumph' tall fescue and 1/3 'Apollo' alfalfa and 2/3 'AU-Triumph' tall fescue mixtures.

Deswysen et al. (1993) noted differences in grazing cyclicity among heifers with different pedigrees for milk production. They also found that individual heifers exhibited different complex rhythm components for both time spent eating and rumination. Figure 4 illustrates behavior variation among steers by presenting periodograms of individual steers on each treatment. In general, steers on each treatment tended to behave as one group, and the major cycles tended to coincide. In some instances, one animal behaved differently from the others (e.g., cycle length = 3.9 h for 2/3A, where steer 542 exhibited a greater ordinate than the other two steers). The steers carrying vibracorders in this study were uniform in body size and age and similar in genetic makeup; therefore, there were no great differences in grazing behavior due to differences in size or production potential. Forage preference studies using sheep followed forage preference on one "focal" ewe because behavior of other sheep in the group could not be assumed to be independent (Parsons et al., 1994). We conclude that using the mean ordinates to describe treatment behavior, as the statistical methods used for comparing treatment spectra required, is adequate in describing behavior for each treatment when the animals are uniform.

Daily sward densities, calculated in 10-cm layers, are presented in Table 2. Initially, the 10- to 20-cm stratum contained the greatest forage density for the A treatment; 839 kg/ha was present in the 10-cm layer. Dougherty et al. (1990) found a similar result; their 10- to 20-cm layer also contained the greatest portion (.48) of alfalfa forage. The 0- to 10-cm layer of the F treatment had the greatest density, 724 kg/ha, of the fescue layers; this shows a dry matter distribution different from that of A. Both mixtures revealed that the 20- to 30-cm layer had the greatest density, and this suggests that their forage distribution differed from that of A and F. By d 6 of grazing, forage remained only in the 0- to 10- and 10- to 20-cm layers. Forage density was greater in the 0- to 10-cm layer than initially, presumably due to the cattle trampling the forage.

General Discussion

This study indicates that steers grazing forages of differing proportions of alfalfa and tall fescue behave differently as they defoliate the pastures. The practice followed in this paper was similar to a rotational grazing system in which pastures are defoliated for 5 d before cattle are moved to the next pasture. Quality of the forage selected by the steers declined as time progressed for alfalfa and alfalfa mixtures; however, quality of the fescue remained relatively constant

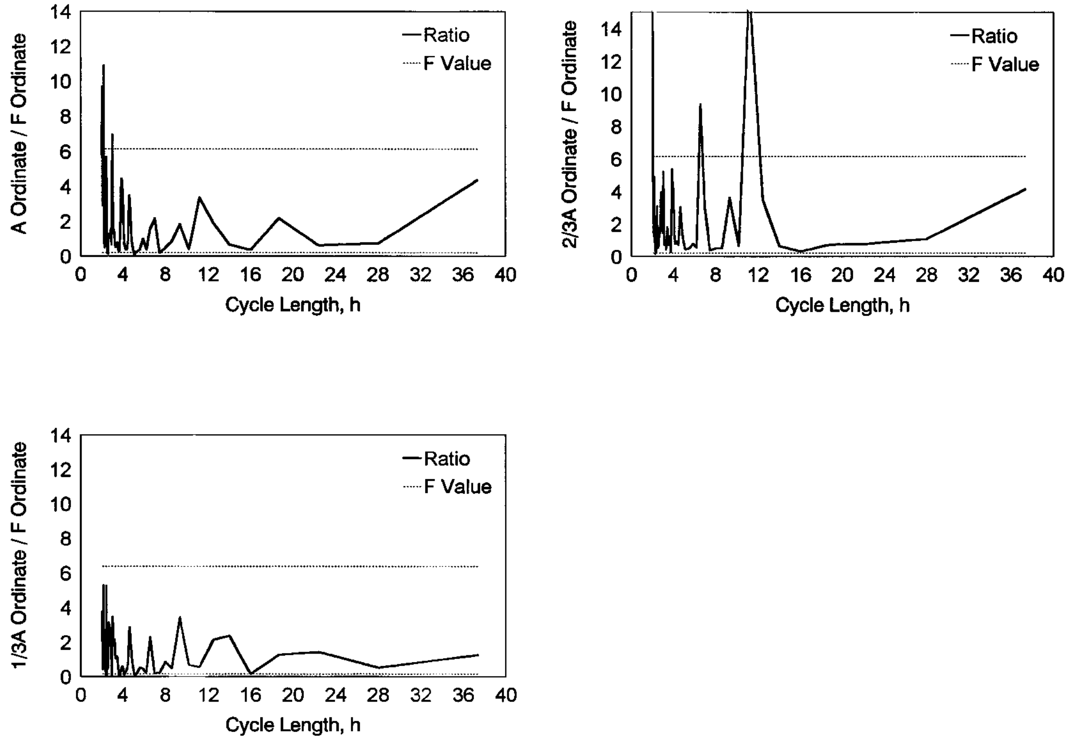

Figure 3. Ratio of ordinates of 'Apollo' alfalfa monoculture and two mixtures to 'AU-Triumph' tall fescue ordinates and associated upper and lower F critical values (α = .10).

during the defoliation. This is logical because it reflects changes in morphology as plants are grazed. Cattle removed the highly digestible leaves from the alfalfa in preference to alfalfa stems. Quality of fescue leaves varied less along the leaf length than quality of alfalfa. A companion study in which steers defoliated similar alfalfa/fescue treatments, but with 'Spreader II' alfalfa, revealed that the percentage of alfalfa leaf selected by steers declined from nearly 70% to approximately 50% as pastures were defoliated for 5 d in July (data not shown). This compared to a decline of alfalfa leaf from 55% to nearly 25% in the ungrazed forage. Unfortunately, forage analyses and composition of leaves and stems could not be made on unconsumed forage reported in this study because of equipment failure. Sheep have been shown to reduce their preference for clover throughout the day (Parsons et al., 1994), and this preference reduction was apparently not related to the amount of clover in the sward. Because the esophageally fistulated steers sampled the forage only once in the morning, this aspect of diet change was not measured. Fistulated steers provided a means of assessing changes in forage quality throughout the study, and not necessarily a measure of what the grazing steers were consuming.

The esophageally fistulated steers potentially could have changed their diet selection depending on the forage they grazed when not on the paddocks and by the degree of fasting. Nonlactating, nonpregnant ewes changed their diet preference for white clover for the 1st h after switching to clover, depending on whether they were exposed to perennial ryegrass or white clover prior to the switch (Parsons et al., 1994). That study was designed to keep forage at a constant height (6 cm), and this was a defoliation study. We think that the rate of change of sward characteristics between days overshadows differences in animal diet selection that may have existed between fistulated and nonfistulated steers.

Sheep deprived of feed for 24 h had greater intake rates than fed sheep. Newman et al. (1994) found that feed-deprived sheep spent less time grazing clover than fed sheep. They used the proportion of the time spent grazing clover during daylight hours as their measure of preference when sheep had access to a clover and a perennial ryegrass monoculture in the same pastures. Because rate of intake was not measured in our study, influence of feed deprivation was not a concern. Our fistulated steers were held without feed, but allowed water, for a shorter time than the sheep reported by Newman et al. (1994) and would be expected to be less affected by the lack of feed. Also, alfalfa and fescue were mixed in our study and were not monocultures in the same paddock; therefore, results of Newman et al. (1994) are not comparable to ours. Fisher et al. (1989) showed that feed deprivation did not affect diet quality selected by fistulated steers. Dougherty et al. (1987) suggested that because heifers exhibited faster intake rates during the 1st h of grazing after an overnight period

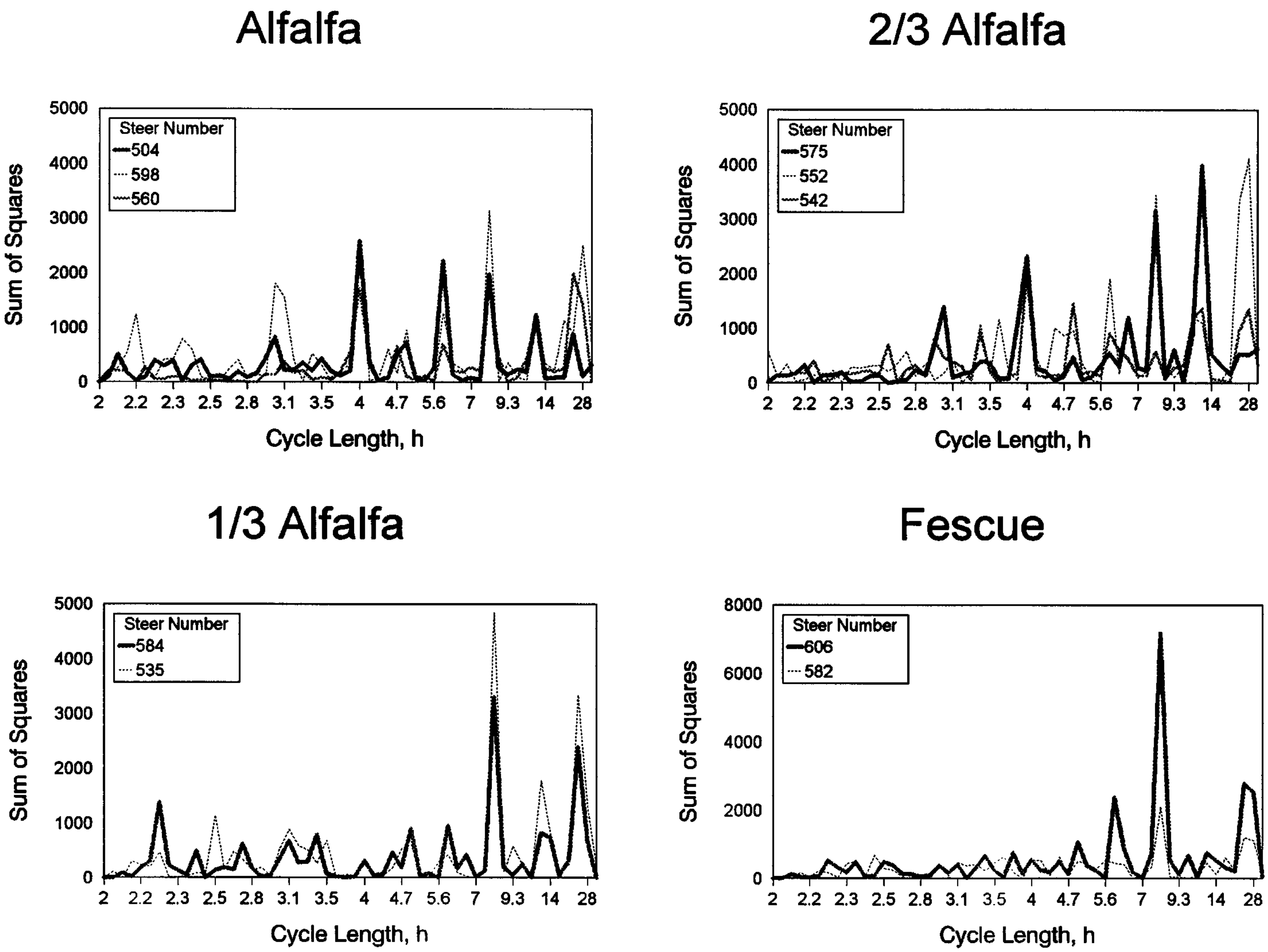

Figure 4. Periodograms of individual steers on each treatment. This figure illustrates variation in grazing cyclicity among steers on each treatment. In general, steer cyclicity tended to coincide for steers on each treatment.

without feed and progressively slower rates during the 2nd and 3rd h, grazing during the 1st h is nonselective, and that as heifers become more satisfied they spend more time selecting. In our case, nonselective grazing by the fistulated steers would make samples more representative of the pasture.

As the defoliation progressed, nearly one-half of the forage was removed; from 683 to 1,527 kg of forage DM/ha was removed. The alfalfa mixtures were initially taller than 40 cm and ended the study 10 to 20 cm tall. Thus, over half of the sward height was removed during the defoliation. Buxton et al. (1985) demonstrated reduced forage quality of the lower portions of alfalfa plants, primarily because alfalfa loses its leaves from lower nodes as plants mature. Therefore, forage remaining at the end of the study would be expected to be lower in quality. Forage amount may have become sufficiently small and short to restrict bite size and herbage intake (Jamieson and Hodgson, 1979).

Forage density seemed to increase from initial values in the bottom layer of forage as defoliation progressed. This increase was more pronounced for the alfalfa treatments than for tall fescue. This increase in density was presumably due to trampling of the forage by the steers; the alfalfa mixtures supported more steers and steer-days than the fescue treatment.

Total time spent grazing was not significantly affected by botanical composition of alfalfa and fescue; however, there was a trend for steers grazing the mixtures to spend more time grazing than those grazing the monocultures. Had more than four experimental units been used, the 1.4 h/d difference between the mixtures and monocultures may have been significant. This would indicate that steers may spend more time selecting diets in mixtures than when grazing monocultures. Errors have been associated with vibracorders on sheep, especially with irregular sward height (Penning, 1983). However, even though vibracorders overestimated grazing time

Table 2. Sward density of alfalfa, tall fescue, and mixtures of the two species by 10-cm layers

Day and layer, cm	Treatment[a]							
	Alfalfa		2/3A		1/3A		Tall fescue	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
	kg/ha							
Day 1								
0–10	675	112	572	405	520	262	724	148
10–20	839	263	615	111	697	208	498	96
20–30	468	63	727	124	777	357	270	89
30–40	169	95	321	132	293	129	23	18
40–50	101	87	115	98	79	4	—	—
Day 2								
0–10	1,481	428	720	229	1,328	679	737	145
10–20	448	219	640	318	440	141	487	68
20–30	176	108	179	126	322	236	73	85
30–40	20	37	53	39	168	171	90	238
40–50	7	13	—	—	122	ND	—	—
Day 3								
0–10	1,388	215	958	393	1,172	371	944	109
10–20	501	119	417	186	462	174	637	466
20–30	158	83	112	15	255	165	—	—
30–40	32	ND[b]	—	—	164	ND	—	—
Day 4								
0–10	1,258	466	671	168	912	390	839	302
10–20	415	174	280	127	348	188	298	165
20–30	233	137	—	—	173	80	—	—
Day 5								
0–10	1,089	465	814	539	1,077	498	758	213
10–20	294	125	337	189	367	198	107	56
Day 6								
0–10	884	567	613	267	940	593	763	254
10–20	175	57	210	80	229	64	69	56

[a]Treatment Alfalfa was pure 'Apollo' alfalfa sowed at a rate of 23.5 kg/ha. Treatment 2/3A was 15.7 kg/ha of 'Apollo' alfalfa sowed with 7.8 kg/ha of 'AU-Triumph' tall fescue. Treatment 1/3A was 7.8 kg/ha of 'Apollo' alfalfa sowed with 15.7 kg/ha of 'AU-Triumph' tall fescue. Treatment tall fescue was 23.5 kg/ha of 'AU-Triumph' tall fescue.

[b]Not discernible, only one measurement.

by 7.5%, Mosley et al. (1987) found no significant difference among vibracorders, electronic clocks, or visual observations.

Steers grazing pastures with a majority of alfalfa and little fescue consumed meals more frequently than steers consuming pastures with more fescue. Penning et al. (1991) showed that mature, nonlactating ewes consumed a larger number of meals of shorter duration when grazing white clover than when grazing perennial ryegrass. Also, ewes had longer idle times when grazing clover than when grazing ryegrass. Steers consuming fescue seemed to have three major grazing periods per day, with a grazing cycle length of approximately 8 h, as compared to A and 2/3A, for which no dominant cycles emerged, only a series of short, frequent meals. Holt (1992) found that steers grazing Russian wildrye had three cycles of grazing per day. The cause of an 8-h cycle length is unknown. An 8-h cycle is a harmonic of 24 h and certainly is a component of the 24-h cycle. It could be a function of photoperiod or other environmental rhythm, and more research would be required to find its cause (Champion et al., 1994).

Because fescue diets contained more NDF than alfalfa diets, steers consuming fescue could be spending the nongrazing time ruminating and digesting. Mature ewes spent less time ruminating when grazing white clover than when grazing perennial ryegrass, presumably because clover leaves have a faster rate of breakdown during mastication than grass (Penning et al., 1991).

For all forage treatments, grazing time was greater on the second full day than on the first (Figure 5). Stuth et al. (1987) found that cows grazed more intensely on d 1 and 2 and less intensely on the following days after being rotated to new pasture cells in a rotational grazing system. Cattle were grazing bermudagrass prior to this study, so the increase may reflect that the steers had to become accustomed to the novel forage. Grazing time on the 5th d was similar to that on the 1st d. Differences in grazing time could indicate that cattle had more opportunity to select on d 2 than on the other days. Possibly, once

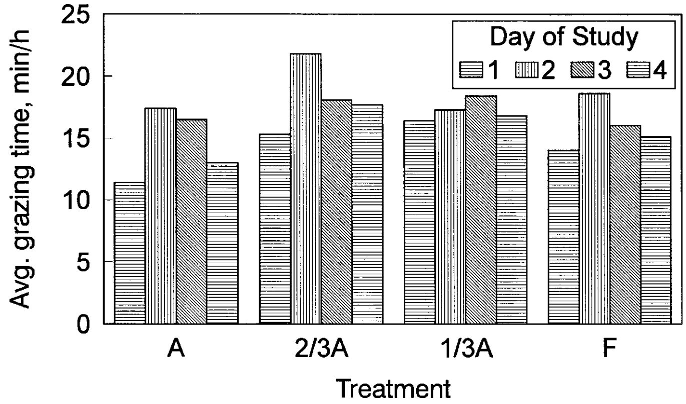

Figure 5. Average time spent grazing for steers grazing 'Apollo' alfalfa (A) and 'AU-Triumph' tall fescue (F) monocultures or 2/3 'Apollo' alfalfa and 1/3 'AU-Triumph' tall fescue (2/3A) and 1/3 'Apollo' alfalfa and 2/3 'AU-Triumph' tall fescue (1/3A) mixtures.

the steers decided what they wanted they spent more time selecting for it. By the end of the study, steers could have reduced total intake because little of the choice forage remained. Because daily intake was not measured, the ways in which reduced grazing time affected intake are unknown.

Even though steers grazing alfalfa spent approximately .75 h/d less time grazing than did steers grazing fescue, estimated alfalfa intake was 1.2 times greater for alfalfa than for fescue, suggesting that intake rate of alfalfa was greater than that of fescue. Penning et al. (1991) showed that mature ewes had 48% greater intake/bite when grazing white clover than when grazing perennial ryegrass. Biting rate was similar for both plant species and resulted in a greater intake of clover than of ryegrass.

The consequences of forage quality, forage amount, forage height, daily intake, and ingestive behavior are all expressed in grazing time and pattern of grazing time. Greatest estimated intake and grazing time occurred in a mixture that was predominately alfalfa (2/3A; 74% alfalfa and 14% fescue). When alfalfa content was 55% (1/3A), grazing time was still high, but estimated intake was reduced, resulting in reduced grazing efficiency.

In a rotational grazing context, cattle should be rotated to the next pasture when the forage quality begins to decline. In these alfalfa and alfalfa mixtures, quality declined more rapidly than that of fescue; this suggests that steers on alfalfa should be rotated to new pastures more rapidly. Steers on fescue may be able to spend more days on a pasture because its quality remains relatively constant during defoliation. Fescue sward height and density affect bite size and intake (Arias et al., 1990), so decisions to rotate cattle on fescue may depend more on forage height or amount rather than on changes in quality.

Cattle should be moved only after their time spent grazing begins to decline. Once grazing time begins to decline due to the absence of choice forage, intake would increase when cattle are moved to another pasture (Jamieson and Hodgson, 1979). Steers grazing with more frequent meals seem to have greater intake than steers eating only three or so times per day. This could result in greater ruminal efficiency because ruminal microbes would be in more of a steady state (Jung and Allen, 1995). These cattle may have ruminated less because the diet was more digestible and contained less fiber. Steers that spend more time ruminating have less time available for grazing and so may have reduced intake and reduced production efficiency (Deswysen et al., 1993).

Implications

Steers grazing different forage species during a defoliation period behave differently. Forage quality seems to alter their grazing behavior by changing rates of intake, digestion, and passage and due to morphological differences among the forage mixtures. For rotational grazing, alfalfa quality should be expected to decline more rapidly than that of tall fescue. Cattle should be rotated to the next pasture when grazing time begins to decline and before an active grazing session to increase intake. Cattle eating frequent meals because of the presence of a legume may be more efficient by virtue of a steady-state ruminal environment than cattle consuming a grass less frequently. Total grazing time alone may not reflect differences in grazing behavior, but spectral analysis may reveal the effect of pasture composition on frequency of meal consumption. Telemetry devices or electronic data recorders could easily be adapted to record grazing information, and the data could be analyzed by spectral analysis.

Literature Cited

Adams, D. C. 1985. Effect of time of supplementation on performance, forage intake and grazing behavior of yearling beef steers grazing Russian wild ryegrass in the fall. J. Anim. Sci. 61:1037–1041.

Arias, J. E., C. T. Dougherty, N. W. Bradley, P. L. Cornelius, and L. M. Lauriault. 1990. Structure of tall fescue swards and intake of grazing cattle. Agron. J. 82:545–548.

Beauchemin, K. A., R. G. Kachanoski, G. B. Schaalje, and J. G. Buchanan-Smith. 1990. Characterizing rumination patterns of dairy cows using spectral analysis. J. Anim. Sci. 68:3163–3170.

Brocklebank, J. C., and D. A. Dickey. 1986. SAS System for Forecasting Time Series, 1986 Edition. SAS Inst. Inc., Cary, NC.

Buxton, D. R., J. S. Hornstein, W. F. Wedin, and G. C. Marten. 1985. Forage quality in stratified canopies of alfalfa, birdsfoot trefoil, and red clover. Crop Sci. 25:273–279.

Chacon, E., and T. H. Stobbs. 1976. Influence of progressive defoliation of a grass sward on the eating behavior of cattle. Aust. J. Agric. Res. 27:709–727.

Champion, R. A., S. M. Rutter, P. D. Penning, and A. J. Rook. 1994. Temporal variation in grazing behavior of sheep and the reliability of sampling periods. Appl. Anim. Behav. Sci. 42:99–108.

Coffey, K. P., J. L. Moyer, F. K. Brazle, and L. W. Lomas. 1992. Amount and diurnal distribution of grazing time by stocker cattle under different tall fescue management strategies. Appl. Anim. Behav. Sci. 33:121–125.

Deswysen, A. G., P. Dutilleul, J. P. Godfrin, and W. C. Ellis. 1993. Nycterohemeral eating and ruminating patterns in heifers fed grass or corn silage: Analysis by finite Fourier transform. J. Anim. Sci. 71:2739–2747.

Diggle, P. 1990. Time Series: A Biostatistical Introduction. pp 94–133. Clarendon Press, Oxford, U.K.

Dougherty, C. T., N. W. Bradley, P. L. Cornelius, and L. M. Lauriault. 1987. Herbage intake rates of beef cattle grazing alfalfa. Agron. J. 79:1003–1008.

Dougherty, C. T., M. Collins, N. W. Bradley, P. L. Cornelius, and L. M. Lauriault. 1990. Moderation of ingestive behavior of beef cattle by grazing-induced changes in lucerne swards. Grass Forage Sci. 45:135–142.

Fisher, D. S., J. C. Burns, and K. R. Pond. 1989. Esophageal plug and fasting effects on particle size distribution and quality of extrusa from grass pastures. Agron. J. 81:129–132.

Forbes, T.D.A. 1988. Researching the plant-animal interface: The investigation of ingestive behavior in grazing animals. J. Anim. Sci. 66:2369–2379.

Fuller, W. A. 1976. Introduction to Statistical Time Series. p 282. Wiley Publishing, New York.

Hill, N. S., J. A. Steudemann, G. O. Ware, and J. C. Petersen. 1989. Pasture sampling requirement for near infrared reflectance spectroscopy estimates of botanical composition. Crop Sci. 29: 774–777.

Holt, N. W. 1992. Forage intake and grazing times of yearling beef steers grazing nitrogen-fertilized Russian wildrye (*Psathyrostachys junecus*). Can. J. Anim. Sci. 72:375–387.

Howard, M. D., R. B. Muntifering, N. W. Bradley, G. E. Mitchell, Jr., and S. R. Lowry. 1992. Voluntary intake and ingestive behavior of steers grazing Johnstone or endophyte-infected Kentucky-31 tall fescue. J. Anim. Sci. 70:1227–1237.

Jamieson, W. S., and J. Hodgson. 1979. The effects of variation in sward characteristics upon the ingestive behavior and herbage intake of calves and lambs under a continuous stocking management. Grass Forage Sci. 34:273–282.

Jung, H. G., and M. S. Allen. 1995. Characteristics of plant cell walls affecting intake and digestibility of forages by ruminants. J. Anim. Sci. 73:2774–2790.

Mosley, J. C., G. W. Reeves, M. A. Maiga, and D. M. Grice. 1987. Electronic clocks for measuring grazing time of free-ranging cattle: A comparison with vibracorders and visual observation. Appl. Anim. Behav. Sci. 18:349–353.

Newman, J. A., P. D. Penning, A. J. Parsons, A. Harvey, and R. J. Orr. 1994. Fasting affects intake behavior and diet preference of grazing sheep. Anim. Behav. 47:185–193.

Parsons, A. J., J. A. Newman, P. D. Penning, A. Harvey, and R. J. Orr. 1994. Diet preference of sheep: Effects of recent diet, physiological state and species abundance. J. Anim. Ecol. 63: 465–478.

Penning, P. D. 1983. A technique to record automatically some aspects of grazing and ruminating behavior in sheep. Grass Forage Sci. 38:89–96.

Penning, P. D., A. J. Rook, and R. J. Orr. 1991. Patterns of ingestive behavior of sheep continuously stocked on monocultures of ryegrass or white clover. Appl. Anim. Behav. Sci. 31:237–250.

SAS. 1985. SAS User's Guide: Basics (Version 5 Ed.) SAS Inst. Inc., Cary, NC.

Seman, D. H., J. A. Stuedemann, and Jon E. Anderson. 1997. Spectral analysis of bovine grazing behavior on *Neotyphodium coenophialum* infested pastures. Appl. Anim. Behav. 54:73–87.

Seman, D. H., J. A. Stuedemann, D. L. Breedlove, S. R. Wilkinson, D. P. Belesky, F. N. Thompson, and F. P. Stewart. 1990. Differences in grazing behavior of steers consuming endophyte-infected or noninfected tall fescue. In: Proc. Int. Symp. on *Acremonium*/grass Interactions, Baton Rouge, LA. pp 267–272.

Stobbs, T. H. 1970. Automatic measurement of grazing time by dairy cows on tropical grass and legume pasture. Trop. Grassl. 4: 237–244.

Stuedemann, J. A., D. L. Breedlove, K. R. Pond, D. P. Belesky, L. P. Tate, Jr., F. N. Thompson, and S. R. Wilkinson. 1989. Effect of endophyte (*Acremonium coenophialum*) infection of tall fescue and paddock exchange on the intake and performance of grazing steers. In: Proc. XVI Int. Grassl. Cong., Nice, France. French Grassland Soc. 2:1243–1244.

Stuth, J. W., P. S. Grose, and L. R. Roath. 1987. Grazing dynamics of cattle stocked at heavy rates in a continuous and rotational grazed system. Appl. Anim. Behav. Sci. 19:1–9.